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PRESSURES ON WALLS of potato storage bins

AMS- 401

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Transportation and Facilities Research Division

PREFACE

The research on which this report is based is part of a project for the development of more efficient work methods, equipment, and facilities for off-farm handling, storage, and preparation for market of fall-crop potatoes. This publication provides information on the pressures potatoes exert on walls of storage bins and gives criteria for the construction of walls to support these pressures. This report was prepared under the supervision of Joseph F. Herrick, Jr., Handling and Facilities Research Branch, Transportation and Facilities Research Division, Agricultural Marketing Service.

The author expresses his appreciation to Wallace Ashby, chief, Livestock Engineering and Farm Structures Research Branch, and W. V. Hukill, head, Grain Harvesting and Drying Section, Harvesting and Farm Processing Research Branch, Agricultural Engineering Research Division, Agricultural Research Service, under whose general supervision the study was initiated and partially completed. Cooperation of the Maine, Colorado, Minnesota, and North Dakota Agricultural Experiment Stations, and of the Red River Valley Potato Growers Association has been helpful in conducting and completing the field studies.

In Maine the research was conducted in the S. J. Hartley storage at Bridgewater. Work in Colorado was carried out in several farm storages and in the Colorado Experiment Station storage at Fort Collins. All of the final stages of the work were done at the Red River Valley Potato Research Center, East Grand Forks, Minn.

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August 1960

SUMMARY

In order to design and construct economical potato storage structures it is necessary to know what pressures potatoes exert on walls and partitions of storages. A series of studies was conducted in Maine, Colorado, and Minnesota to determine these pressures. Maine and Colorado studies were based on the deflection of calibrated wood planks in bin walls. Pressure cells made of two steel discs were also tried at Colorado. In the Minnesota tests, pressures were measured by the deflection of calibrated steel bars supporting vertical wall panels.

Early analyses showed that potato pressures on bin walls followed the same pattern as ear corn but were lower. Potato pressures were found to increase with time both in tests and in practice. More partitions fail as an adjoining bin is emptied than when a bin is filled next to one that is empty. Settling of potatoes may leave voids, into which potatoes later may wedge, due to vibration. Vibration caused by passing trains and trucks is more noticeable after the ground freezes. But vibration due to an avalanche of potatoes in an adjoining bin, together with sudden release of supporting pressure, often causes failure in a partition designed for a static load. Within the limits of deflections observed, there is little difference in the unit pressure on the front and sides of a bin, which is longer than it is wide.

Horizontal pressure on partitions or walls at the floor drops due to friction of potatoes on the floor. Vertical pressure of potatoes on the wall reduces the load the floor must support. In narrow bins 20 feet deep, this has a measurable effect, for the walls carry a load equal to the weight of potatoes 1.2 feet in from each wall. Bins with partitions 8 feet on centers have a net width between partitions of 7.2 feet of potatoes. The bin floor carries only 67 percent of the potato weight, the remaining 33 percent is carried by friction on the wall. Bins with partitions 10 feet on centers have a net width between partitions of 9.2 feet of potatoes; 74 percent of the potato weight is carried on the floor; the remaining 26 percent is carried by the wall.

Studding, posts, and sheathing can be chosen for sound walls, partitions, and bin fronts. Usually 2-foot spacing of studding is recommended for outside walls which are to be sheathed, insulated, and weatherproofed. For bin partitions, post spacing of 8 feet on centers with plank spiked to one side is most economical if roof framing can be supported on posts. Posts treated at the bottom with a fungicide like pentachlorophenol and set in sockets formed in the concrete floor will resist side thrust and outlast other parts of the structure. At the top where stress is lower, posts may be bolted or spiked with angle iron to ceiling beams. Studding-type walls can be secured to the sill with metal clips, angle iron, or spikes. The sill should be anchored with 5/8-inch anchor bolts spaced 2 feet apart and set into a concrete curb. In choosing between lumber, plywood, or corrugated sheet metal for sheathing the cost of material for covering comparable areas should be checked at local outlets to determine which is the most economical. Consideration should also be given to the amount of labor and waste involved with the use of each material.

POTATO PRESSURES ON WALLS OF STORAGE BINS

By Alfred D. Edgar, agricultural engineer,
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BACKGROUND

The design and construction of potato storage walls and partitions have usually been matters of trial and error. 1/ Sometimes the assumption was that potatoes exert the same pressure against the sides of bins as grain. In some cases builders have made the walls stronger than necessary, to support the weight of grain, but more often, with no design criteria available, they have made the walls too weak rather than too strong.

Failure of many potato storage walls or partitions in Maine because of inadequate strength prompted the study of potato pressures on storage walls. Initial studies were made by comparing the deflection of partition planks stressed by potatoes with the same kind of planks stressed by known weights. A rough approximation was obtained but the data were too variable and erratic to be useful. Later determinations of potato pressure were made in Colorado by means of both plank deflection and hydraulic pressure cells. The hydraulic pressure cells consisted of two steel discs welded together at the periphery with provisions for reading the pressure exerted upon them. These cells are described in detail later. In the Maine studies, potato depths were from 4 to 19 feet; and in Colorado, depths were from 4 to 8 feet. The results of the two studies gave a fair picture of potato pressures on the walls but there were far too many questionable readings for the data to be considered entirely satisfactory. To improve on the plank deflection data from Maine and Colorado, water pressure cells were made, calibrated, and used. These, when placed in bins, also failed to give consistent results.

Continued need for potato pressure data led to a better controlled series of tests at the Red River Valley Potato Research Center at East Grand Forks, Minn. The method involved the use of pressure panels and was the same as that used by McCalmont and Ashby in determining ear corn pressures. 2/ The pressure panels, which were supported by calibrated steel bars, were installed in the bin walls. The defects of the plank deflection method were eliminated and reliable data on the pressures of potatoes on storage walls were determined. Data on pressure and on the known strength of structural members taken from other sources have been combined in tables. From these tables it is possible to select the appropriate dimensions for sheathing, planks, studding, and posts to be used in walls, partitions, and bulkheads for bins of various depths.

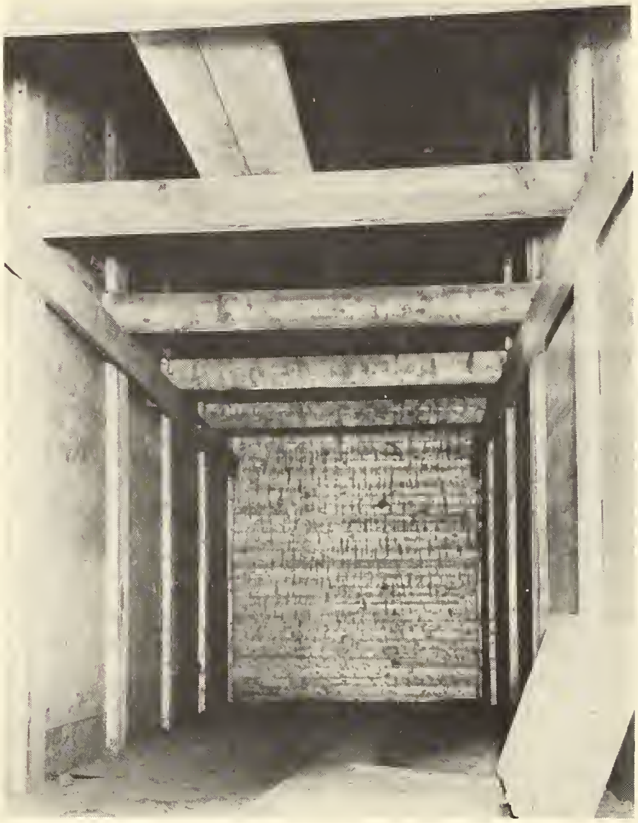
1/ As used in this report, a wall is considered to be part of the structure itself while partition is an interior wall used to separate the storage structure into bins. In discussions that follow walls and partitions may be used interchangeably in discussing pressures.

2/ McCalmont, J. R., and Ashby, Wallace. Pressure and Loads of Ear Corn in Cribs. Agr. Engin., Vol. 15, No. 4, April 1934.

PRESSURE TESTS

In Maine

Studies were conducted in a commercial potato storage located in Bridgewater, Maine. Deflection of planks in bin partitions was measured in September and the same planks were calibrated with no-load and test loads the following July (fig. 1). Results of these tests were too inconsistent to allow definite conclusions.



BN 9369-X

Figure 1.--Storage bin in Maine in which deflection of planks in wall were measured. Note edge to edge contact of planks set in between supporting posts of bin.

In Colorado

Studies of potato pressures on walls were later continued in Colorado. Potato pressures were determined the first year by measuring the deflection of uncalibrated planks in bin walls and calculating the pressures based on an assumed modulus of elasticity; the next year by measuring deflection of planks under a known load and calculating pressures from unknown loading; and the following year an attempt was made to determine pressures by using calibrated metal water pressure cells.

These pressure cells were made of two 16-inch diameter, 26-gage steel discs sealed together at their periphery. One disc was drilled at the center and a 1/4-inch pipe connected to it. The cells were calibrated by placing them in a vertical plane in a test barrel with standpipe. The 1/4-inch pipe extended through a hole in the side of the barrel and low pressures were read by means of a glass sight gage and high pressures by a dial gage. The cells were filled with water and all cells were found to measure accurately the pressure in the test barrel.

The tests were conducted in commercial storages and in the campus storage at Colorado A. and M. College, Fort Collins, Colo. 3/ Results of these tests with planks also were not conclusive. In addition, the pressure cells failed during the tests so no data were obtained with them.

Data developed from the plank tests during the first two years are shown in figure 2. The curves indicate the relationship of horizontal pressures to depth of potatoes. The curve for the second year's tests is considered to be a good one to follow for design pressures up to a depth of 8 feet. For greater depth, the pressures recorded from the first year's tests of potatoes piled 8 to 18 feet deep seems too low. Note how the curves for the two years do not meet on the figure.

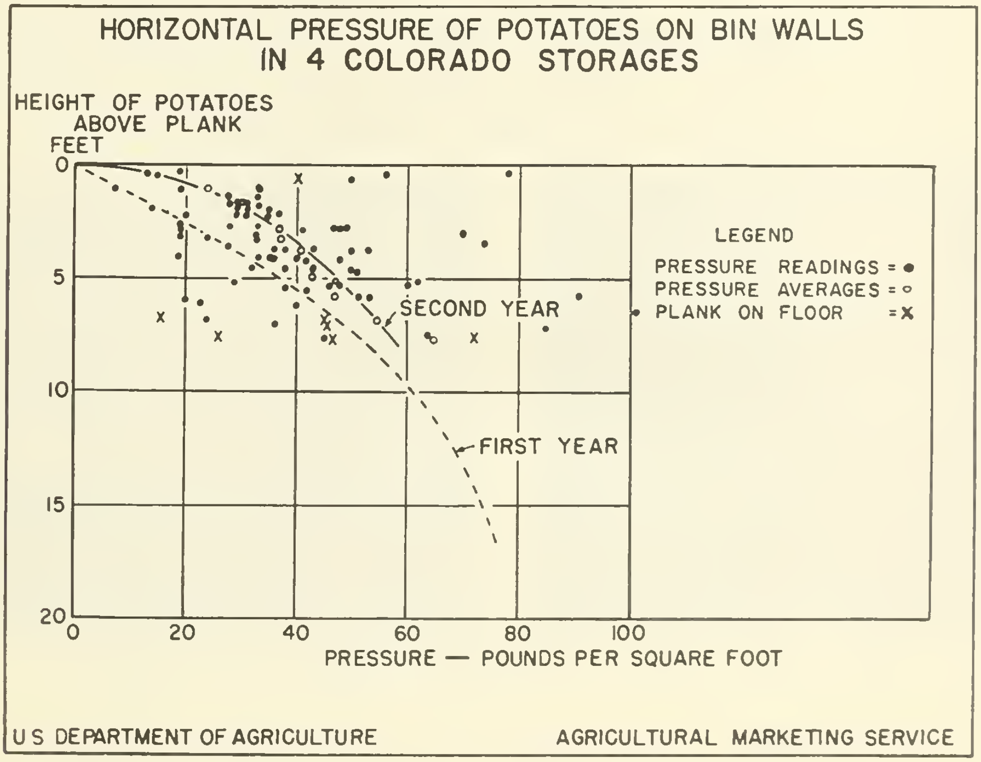


Figure 2

3/ Now Colorado State University.

At the Red River Valley Potato Research Center, East Grand Forks, Minn.

Studies of pressures of potatoes on bin walls were continued at the Red River Valley Potato Research Center at East Grand Forks, Minn., for about 4 years. In these tests pressures were determined from the deflection of steel bars supporting vertical wall panels in the same manner used by McCalmont and Ashby in determining pressure of ear corn on cribs. With steel bars supporting the panels, both horizontal and inclined pressures were determined. In the tests conducted with planks in the earlier studies in Maine and Colorado, results were erratic and inconsistent because of the variation in the moisture content of the wood, and the planks resting one on the other and on the floor. The bar-supported panels had a 1/4-inch clearance on all edges permitting free movement of each panel which allowed independent readings to be obtained for each level.

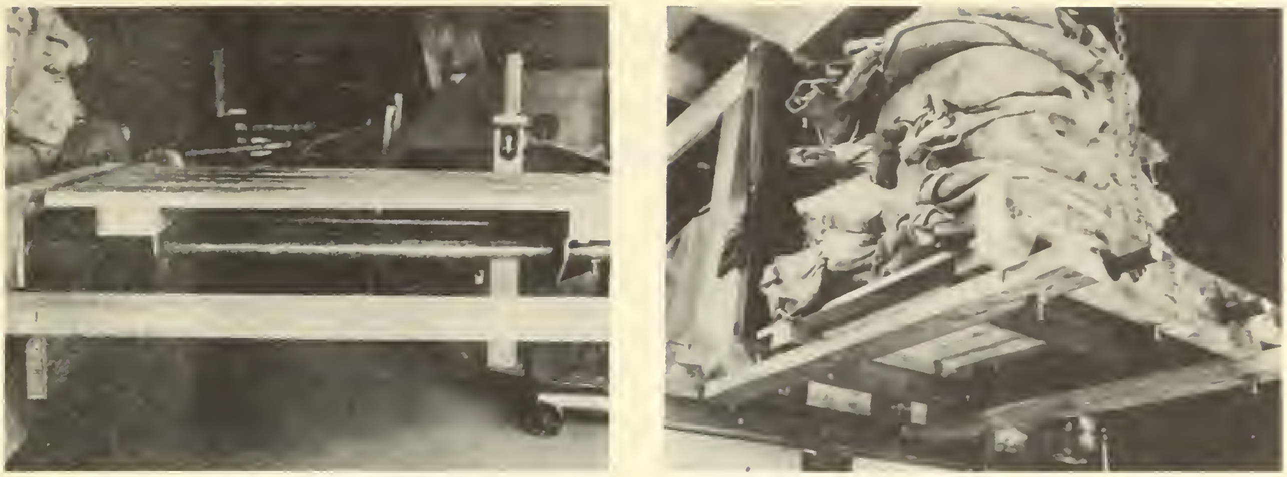
Procedure

At the Research Center, the pressure studies were made in bins 10 feet wide, 18 feet long, and 20 feet high. The tests conducted during the first season covered pressures for potatoes at 10- to 20-foot depths. During the three following seasons, pressures were determined for 1- to 20-foot depths.

To determine these pressures the amount of deflection, or bending, of 1- and 1-1/8-inch diameter steel bars supporting 2- by 3-foot vertical panels inserted in the bin walls was measured and from this amount of deflection the computations were made of the pressure exerted against the panel by the potatoes in the storage bin.

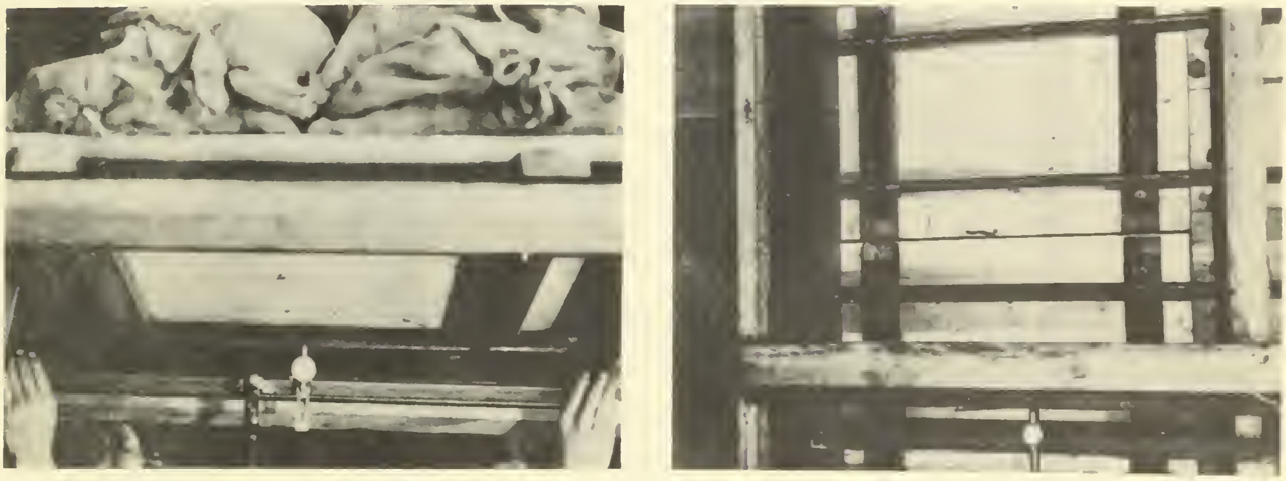
The 2- by 3-foot test panels were constructed of 1-inch dressed and matched (D&M) spruce on 2- by 4-inch frames to which 3- by 3-inch steel angles were bolted. These steel angles were drilled with 1½-inch diameter holes 18 inches on centers through which the 54-inch-long test bars were inserted. A test frame was constructed for calibrating the steel bars and panels in a horizontal plane to compare with the potato pressures when the panels and bars were placed in test position in a vertical plane (fig. 3).

Test loads were applied to each set of panel and bars while in calibrating position as shown in figures 3 and 4(A) equivalent to 50, 100, 150, 200, 250, and 300 pounds per bar. Figure 4(B) shows the panels in test position to take potato pressures. The deflections of the bars under test loads are tabulated in table 1. Note relatively uniform deflection for all 1-1/8-inch bars (numbers 1 to 14 inclusive) and for 1-inch bars (numbers 15 to 20 inclusive).



(A) BN-9366-X (B) BN-9373-X

Figure 3.--Two by three ft. pressure panels in test frame. Unloaded panel (A) and loaded panel (B) with 1-1/8-inch test bars in place for calibration.



(A) BN-9372-X (B) BN-9371-X

Figure 4.--Panels in calibration position (A) and in test position in bin for pressure determinations (B). Note holding of bar gage and spirit level (A) and gage bar on check straight edge (B).

Table 1.--Deflection of test bars on 40-inch span for various weights when panel is supported in horizontal plane for calibration

Bar number	Diameter	Deflection of test bars when loading per bar in pounds is:					
		50	100	150	200	250	300
	Inches	Inches	Inches	Inches	Inches	Inches	Inches
1	1.12	0.018	0.030	0.048	0.066	0.083	0.100
2	1.12	.014	.030	.044	.056	.070	.082
3	1.12	.018	.035	.048	.064	.080	.092
4	1.12	.017	.032	.052	.070	.088	.105
5	1.12	.018	.036	.053	.069	.083	.098
6	1.12	.018	.034	.050	.067	.084	.104
7	1.12	.014	.033	.048	.064	.080	.096
8	1.12	.012	.028	.047	.063	.077	.094
9	1.12	.016	.031	.046	.062	.075	.090
10	1.12	.016	.032	.048	.066	.082	.096
11	1.12	.015	.029	.046	.062	.078	.091
12	1.12	.015	.032	.049	.063	.076	.093
13	1.12	.018	.033	.049	.065	.076	.088
14	1.12	.015	.030	.046	.058	.077	.095
15	1.0	.026	.051	.076	.103	.120	.138
16	1.0	.024	.050	.063	.096	.124	.152
17	1.0	.024	.053	.079	.105	.129	.153
18	1.0	.024	.047	.069	.094	.115	.136
19	1.0	.026	.054	.081	.105	.130	.153
20	1.0	.023	.044	.068	.092	.114	.133

Calibration curves of these values are plotted in figure 5. Shown on the same figure are the reference lines obtained for both 1-inch and 1-1/8-inch diameter bars by using the standard deflection equation:

$$D_w = W_a \, (3/4 \, L^2 - a^2)/12 \, EI$$

From which $W = 3198 \, D_w$ for 1-1/8-inch diameter bars and
$W = 1997 \, D_w$ for 1-inch diameter bars
where D_w = deflection in inches
W = total weight applied or supported per bar
a = distance from support to where weight is applied to bar
L = Length of span between supports = 39.5 inches
E = modulus of elasticity of steel bars = 30,000,000 pounds per square inch
I = .07856 inch^4 for 1-1/8-inch diameter bar
I = .04909 inch^4 for 1-inch diameter bar

After the bars were calibrated the panels were installed in the front of a bin as shown in figure 4(B). Two bars supported each 2- by 3-foot panel. A layout of the test bin is illustrated in figure 6. A plate 1/4 inch thick, 4 inches wide, and 20 feet long was bolted to wood posts spaced 40 inches apart in the bin. Holes 1-1/2 inches in diameter were drilled in these plates and were

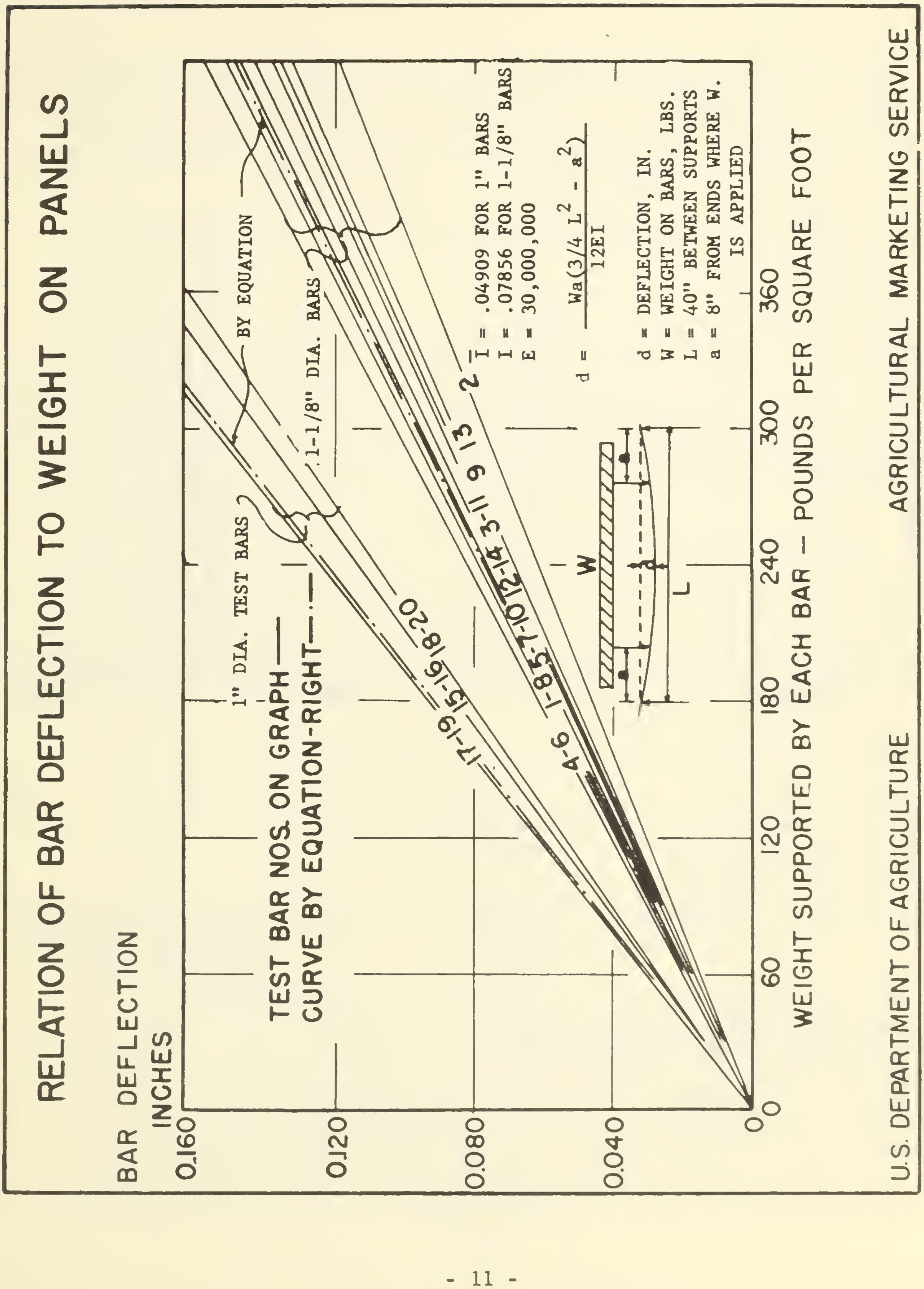

RELATION OF BAR DEFLECTION TO WEIGHT ON PANELS
BAR DEFLECTION
INCHES
0.160
0.120
0.080
0.040
0
0
60
120
180
240
300
360
WEIGHT SUPPORTED BY EACH BAR — POUNDS PER SQUARE FOOT
TEST BAR NOS. ON GRAPH
CURVE BY EQUATION-RIGHT
1" DIA. TEST BARS
1-1/8" DIA. BARS
BY EQUATION
17-19
15-16
18-20
4-6
1-8
5-7
10
12-14
3-11
9
13
2
I = .04909 FOR 1" BARS
I = .07856 FOR 1-1/8" BARS
E = 30,000,000
d = Wa(3/4 L² - a²) / 12EI
d = DEFLECTION, IN.
W = WEIGHT ON BARS, LBS.
L = 40" BETWEEN SUPPORTS
a = 8" FROM ENDS WHERE W. IS APPLIED
W
L
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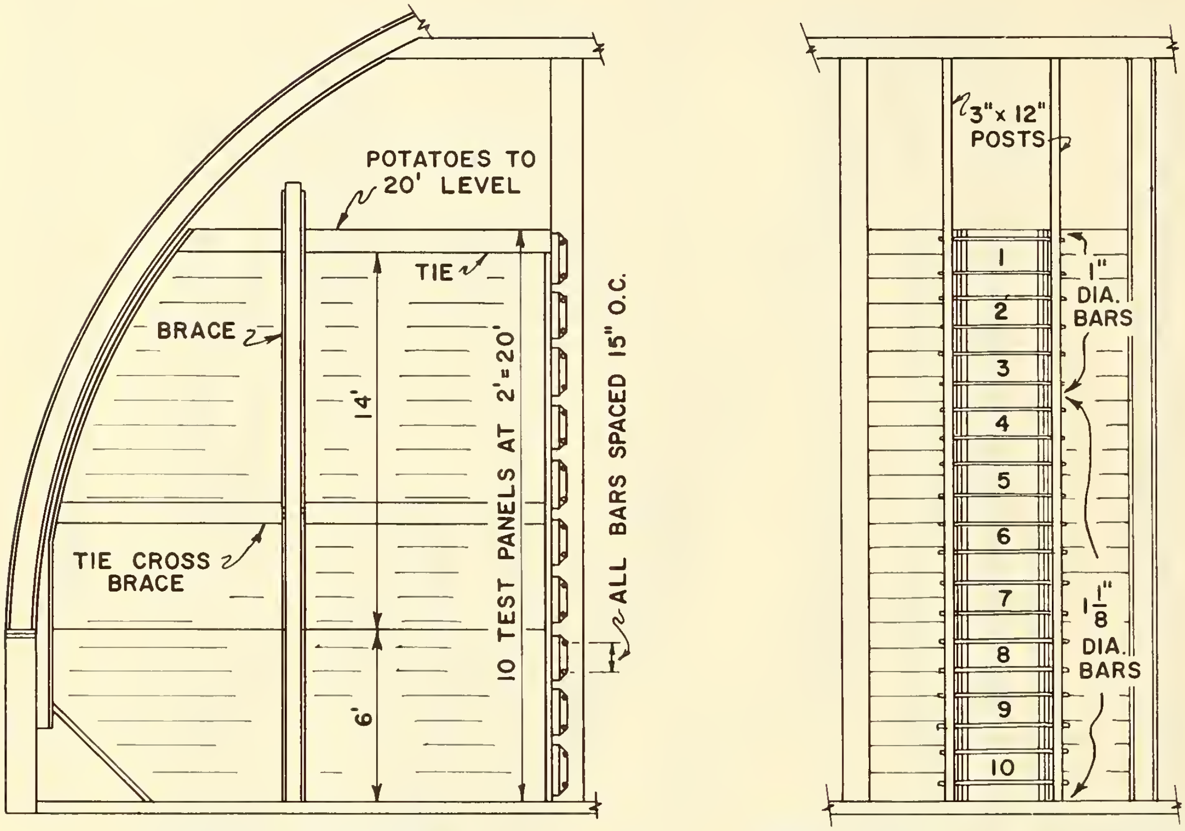
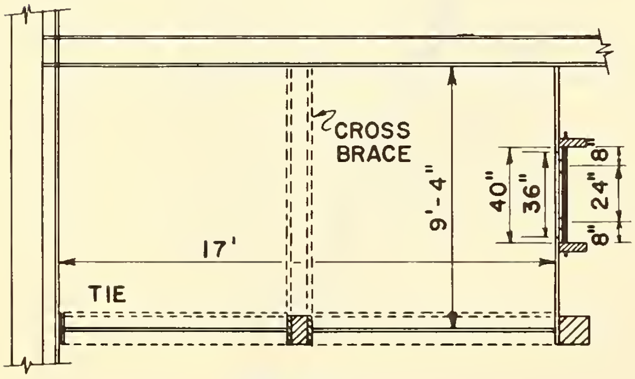
Figure 5

PLAN, CROSS SECTION, AND ELEVATION OF TEST PANELS IN BIN FRONT



CROSS SECTION

BIN FRONT ELEVATION



PLAN

NOTE: 1" BARS SUPPORT TOP 3 PANELS AND 1 1/8" BARS THE LOWER 7 PANELS.

Figure 6

aligned with those drilled in the angle iron in the test panels. The posts to which the 1/4- by 4-inch plates were bolted were drilled with 2-inch-diameter holes so the bars holding the panels would be supported entirely by the steel plate and the posts carried the lateral thrust of potatoes transmitted by the panels and bars.

The bin was then filled with potatoes. Following the filling and at intervals throughout the storage season the amount of deflection or bending of the bars was measured with a bar gage. Because the panels were free to move with both the horizontal and vertical pressures of the potatoes both of the pressures could be determined by the proper measurements of the deflection of the steel bars holding the panels.

These tests and measurements were conducted during four storage seasons.

Results

The bar deflections were measured and the pressures in pounds per sq. ft. were determined by reading directly from the calibration curves (fig. 5). These values are tabulated in table 2. Note in this table the pressures for the depths of potatoes above center of panel are averages of that determined for the upper and lower bars supporting the panel. These data are based upon initial depth, although an original 20-foot pile of potatoes may settle as much as 2 feet in 6 months. This is due both to shrinkage and settling; there was some vibration from passing trains and trucks.

Data of table 2 are plotted in figure 7. Here curves show average horizontal pressure of potatoes in bins ranging 1 to 19 feet in depth. Note considerable scatter of pressure points. This scatter reflects a real condition: (1) As potatoes shrink, they press into adjoining potatoes and exert very little lateral pressure against the walls then; (2) due to vibration they may shift and wedge between adjoining potatoes occasionally causing relatively high pressures. It is with such shifting that bins frequently fail.

Since the maximum pressure was at an angle downward from the horizontal its vertical component (D_v) was calculated using the relationship, $\sin 37.5^\circ D_m = D_v$, (or $0.6088\ D_m = D_v$) and is tabulated in table 3. Here, as in horizontal pressures, the variation in pressure with time was large.

It will be noted that the curve calculated by use of the standard formula agrees very well with measured deflections. After deflections of the bars were determined in the bin, potato pressures at each location were determined by reference to figure 7.

The 1-inch-diameter bars were used in top of test bin and the 1-1/8-inch bars in the lower part. A cross brace through the approximate center of the bin ran parallel to and 9 feet from the nearest pressure panel. It is possible that this brace may have resulted in readings different from what would have been found for an open bin of the same dimensions. In making the readings the gage was first held to read horizontal deflections and checked with a spirit level, then the gage bar was rotated around the test bar as an axis, keeping end legs and gage arm against the cylindrical bar surface until maximum deflection was found. Angle of maximum deflection (37.5° with horizontal) in

Table 2.--Calculated horizontal pressure in pounds per square foot for potatoes in bins 1/

Depth from top of pile to center of panel	Indicated pressures										
	1st year				2nd year		3rd year		4th year		Average
Feet	psf	psf	psf	psf	psf	psf	psf	psf	psf	psf	psf
1	--	--	--	--	30	0	2	6	12	8	
	--	--	--	--	27	27	12	12	12	4	13
3	--	--	--	--	63	35	7	22	15	29	
	--	--	--	--	24	26	16	8	41	28	26
5	---	--	--	--	34	22	32	32	46	20	
	--	--	--	--	19	40	36	36	12	--	30
7	--	--	--	--	66	78	68	74	62	50	
	--	--	--	--	38	78	51	56	68	28	60
9	--	--	--	--	92	60	78	88	56	66	
	--	--	--	--	50	98	55	62	48	73	69
11	50	67	80	67	74	71	100	78	59	44	
	72	68	62	85	62	78	51	90	29	48	67
13	72	64	70	72	84	80	74	81	72	72	
	77	80	80	76	63	84	62	70	54	74	73
15	92	93	93	90	88	102	78	92	86	92	
	90	76	94	92	97	92	70	83	89	94	89
17	77	92	92	94	106	80	122	84	89	72	
	95	78	101	100	104	123	96	102	56	82	92
19	84	99	107	106	86	83	98	100	102	99	
	99	90	104	106	78	104	104	110	78	108	97

1/ Based on the deflection of calibrated round steel bars 1 and 1-1/8 inches in diameter by 2- by 3-foot panels set in a horizontal plane holding potatoes piled bulk in a bin.

the bin was measured by spirit level and checked by the equation:

$$D_h/D_m = \cos 37.5^\circ$$

from which $\cos 37.5^\circ D_m = D_h$ substituting value of $\cos 37.5^\circ = 0.7934$ becomes $0.7934 D_m = D_h$ from which vertical pressure was determined by equation

$$\sin 37.5^\circ D_m = D_v$$

substituting value of $\sin 37.5^\circ = 0.6088$ becomes $0.6088 D_m = D_v$

where D_h = Horizontal deflection in inches

D_m = Maximum deflection in inches

D_v = Vertical deflection in inches

Table 3.--Calculated vertical pressures of potatoes on bin walls in pounds per square foot, Red River Valley Potato Research Center

Depth from top of pile: to center of panel	Calculated vertical pressures 1/										
	1st year				2nd year		3rd year		4th year		Average
Feet	psf	psf	psf	psf	psf	psf	psf	psf	psf	psf	psf
1	--	--	--	--	12	15	4	4	3	12	
	--	--	--	--	4	9	11	4	10	8	8
3	--	--	--	--	34	26	6	12	14	32	
	--	--	--	--	27	12	11	10	24	31	20
5	--	--	--	--	--	2	26	22	30	36	
	--	--	--	--	--	43	26	26	5	17	23
7	--	--	--	--	38	62	64	64	69	21	
	--	--	--	--	58	58	62	63	28	14	50
9	--	--	--	--	55	53	72	68	66	38	
	--	--	--	--	56	68	55	86	38	44	58
11	53	75	76	74	61	64	69	70	85	50	
	76	62	72	74	64	66	51	75	46	68	66
13	38	42	39	43	41	40	30	29	30	36	
	39	44	42	32	22	29	26	31	32	38	35
15	35	28	28	30	21	52	70	46	42	42	
	30	24	28	28	28	35	40	50	34	43	37
17	40	56	52	50	78	87	86	108	84	74	
	49	44	52	48	86	80	78	84	52	82	68
19	64	82	81	84	51	74	76	63	96	77	
	86	70	80	81	62	61	90	84	58	80	75

1/ Panels were calibrated in horizontal plane, where deflections of bars were measured under known loading. Relation of deflection to load per sq. ft. for each bar is plotted in figure 5. From these deflections horizontal and maximum pressures were determined. Horizontal and maximum pressures on panel corresponded to maximum deflection was at some angle downward from horizontal and is made up of horizontal (known) and vertical (unknown) components. The vertical components, tabulated in this table were determined by this method: $D_h/D_m = \cos 37.5^\circ$, $\cos 37.5^\circ D_m = D_h$; $(0.7934 D_m = D_h)$ $\sin 37.5^\circ D_m = D_v$ $(0.6088 D_m = D_v)$

When 37.5° a = includes angle between horizontal and direction maximum force

D_h = horizontal deflection in inches

D_m = maximum deflection in inches

D_v = vertical deflection in inches

(Note since angle of maximum deflection is constant, actual angle of 37.5° is used instead of a.)

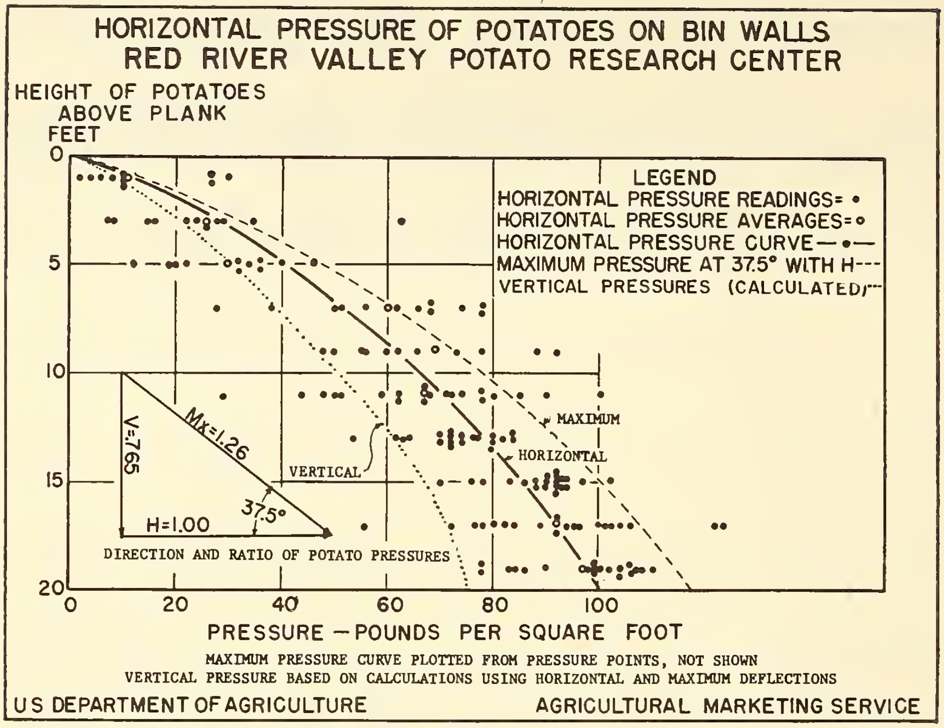


Figure 7

The values developed in table 3 have been plotted in figure 8. Some of the large variations in the data are due to test bars having been bent. This is more noticeable in measuring the inclined than the horizontal pressures. However, the data are useful for the purposes intended.

Curves in figure 7 show maximum and vertical pressures in addition to horizontal pressure. As shown in the triangle on this figure, the slope of maximum pressure is the angle of repose of potatoes.

Early potato pressure determinations indicated that potato pressures were between 80 and 140 pounds per square foot (psf) for 20-foot depth. However, the final series of tests fixed the value at 100 psf for 20-foot depth. This is believed to be a sound basis for safe storage design.

DESIGN OF BIN WALLS

The vertical pressures of potatoes given in table 3 and figure 8 are used only with horizontal pressures to obtain maximum pressures. The maximum pressure is equal to 126 percent of horizontal pressure at an angle of 37.5° with the horizontal. This is an important factor to be considered in non-vertical partition and non-horizontal floor design. In vertical bin wall design, only the horizontal pressures shown in table 2 and figure 7 need be used. The strength of sheathing and structural members are available from numerous sources. The use of these data facilitates selecting appropriate substitute members when the most economical member is not stocked or available.

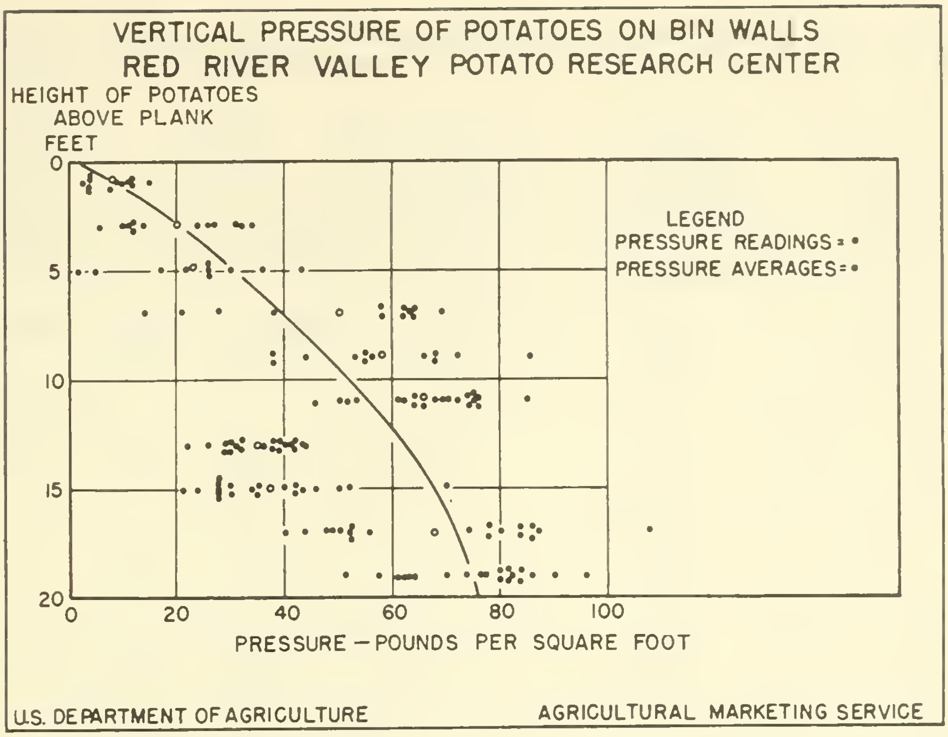


Figure 8

Resultants of Horizontal Potato Pressures

The resultants of horizontal pressures were determined for selected depths of potatoes. The resultants and elevations of the centroids of these pressures are tabulated in table 4. [4] This table also includes sill and plate reactions and maximum bending moments for selected potato depths and wall heights. The method of calculating reaction and bending moment are shown at bottom of this table.

Resisting Moments of Selected Building Lumber, Plywood, and Steel Units

The bending moment in a wall caused by potato pressure must be balanced by the resisting moment of framing member or sheathing. The resisting moments of selected lumber, plywood, and corrugated sheathing, size, grade, thickness, or gage has been tabulated. Use of these tabulations permits selecting the most economical member available when range of size, grade or gage of structural material is limited.

Table 5 shows relative strengths of rough and dressed lumber of selected sizes used for sheathing, studding, or posts. Board measure per foot of length is included for ready reference. The resisting moments of 1,200 and 1,600 psi

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[4] As used here "resultant" means one force in opposite direction to balance all forces from potatoes when at the centroid. For vertical forces this is at the center of gravity. For other directions "centroid" is used. Sill and plate reactions are two forces in opposite directions to total potato forces, also sill plus plate reactions equal the resultant force.

Table 4.--Reaction forces at sill and plate, and bending moment for various depths of potatoes and wall heights for each foot of wall length

Depth of potatoes	Height of wall (H)	Height of centroid of 1/ horizontal potato pressure (h)	Horizontal pressure of potatoes at centroid (P)	Reaction force 2/		Bending moment at centroid of horizontal pressures 3/ (M_x)
				At sill (R_s)	At plate (R_p)	
Feet	Feet	Feet	Pounds	Pounds	Pounds	Inch-pounds
4........	8	1.4	70	58	12	488
4........	10	1.4	70	60	10	505
6........	8	2.2	150	109	41	1,440
6........	12	2.2	150	122	28	1,610
8........	10	2.82	252	181	71	3,030
8........	14	2.82	252	201	51	3,400
10........	12	3.56	375	264	111	5,650
10........	16	3.56	375	291	84	6,220
12........	14	4.3	516	358	158	9,330
12........	18	4.3	516	393	123	10,200
14........	16	5.1	673	458	215	14,000
14........	20	5.1	673	501	172	15,300
16........	18	5.83	844	571	273	20,000
16........	22	5.83	844	621	223	21,800
18........	20	6.6	1,028	689	339	27,600
18........	24	6.6	1,028	746	282	29,500
20........	22	7.38	1,223	813	410	36,000
20........	26	7.38	1,223	876	347	38,800

1/ Centroid is a point where all forces on a member are in balance. With vertical forces it is called center of gravity. Note it is not at center of height. All forces multiplied by their distance on one side from centroid just equal all forces on other side multiplied by their distance from centroid.

2/ Reaction at sill and plate are determined in this manner:

$$R_s + R_p = P \quad R_p = Ph/H$$

where R_s = Reaction force at sill in pounds
R_p = Reaction force at plate in pounds
h = Height of centroid of horizontal potato pressure in inches
P = Horizontal pressure of potatoes at centroid
H = Height of wall in inches

3/ Bending moment at center of horizontal potato pressure (according to figure 7) $M_x = R_s\ h/2$ where R_s = reaction at sill in pounds and h = height of centroid horizontal potato pressure in inches.

Table 5.--Relative strength of certain dressed and rough lumber, sizes of common grade and structural grade lumber used for sheathing, beams, and studding 1/

Lumber						Resisting strengths or moments ($M = Sbh^2/6$)			
Item	Rough size		Dressed size 2/		Amount per linear foot	Stress grade (1,200 psi)		Stress grade (1,600 psi)	
	b	h	b	h		Dressed	Rough	Dressed	Rough
	In.	In.	In.	In.	Bd.-ft.	In.-lb.	In.-lb.	In.-lb.	In.-lb.
Sheathing	12	1	11-1/2	25/32	1	1,400	2,400	1,870	3,200
	12	2	11-1/2	1-5/8	2	6,070	9,600	8,080	12,800
	12	3	11-1/2	2-5/8	3	15,800	21,600	21,200	28,800
	12	4	11-1/2	3-5/8	4	30,000	38,400	40,000	51,200
Studding and posts									
	2	4	1-5/8	3-5/8	2/3	4,272	6,396	5,696	8,528
	4	4	3-5/8	3-5/8	1-1/3	9,528	12,804	12,704	17,072
	2	6	1-5/86	5-5/8	1	10,284	14,400	13,712	19,200
	2	8	1-5/86	7-1/2	1-1/3	18,276	25,596	24,368	34,128
	4	6	3-5/8	5-5/8	2	22,944	28,800	30,592	38,400
	2	10	1-5/8	9-1/2	1-2/3	29,328	39,996	39,104	53,328
	4	8	3-5/8	7-1/2	2-2/3	40,776	51,204	54,368	68,272
	2	12	1-5/8	11-1/2	2	42,984	57,600	57,312	76,800
	6	8	5-1/2	7-1/2	4	61,872	76,800	82,496	102,400
	4	10	3-5/8	9-1/2	3-1/3	65,434	80,004	87,248	106,672
	4	12	3-5/8	11-1/2	4	95,880	115,200	127,840	153,600
	6	10	5-1/2	9-1/2	5	99,276	120,000	132,368	160,000
	6	12	5-1/2	11-1/2	6	145,476	172,800	193,968	230,400
	8	12	7-1/2	11-1/2	8	198,372	230,400	264,496	307,206
	8	14	7-1/2	13-1/2	9-1/3	273,372	313,596	364,496	418,128
	10	14	9-1/2	13-1/2	11-2/3	346,272	392,004	461,696	522,672
	8	16	7-1/2	15-1/2	10-2/3	360,372	409,596	480,496	546,128
	10	16	9-1/2	15-1/2	13-1/3	456,480	512,004	608,640	682,672
	12	16	11-1/2	15-1/2	16	552,576	614,400	736,768	819,200

1/ From National Lumber Manufacturers Association "Wood Structural Design Data." Vol. 1. 1956

2/ Surfaced four sides (S4S)

Note in this table b = width perpendicular to loading; h = depth parallel to loading; and S = stress in pounds per square inch.

stress-grade both dressed or surfaced four sides (S4S) and rough sizes are also included. Note that the rough pieces of the 1,200 psi grade are often stronger than the S4S pieces of the 1,600 psi grade. Note also that greater strength is always secured in the piece that is relatively deep in direction of the pressure. The reason is shown in the resisting moment formula: $M_R = Sbh^2/6$

where S = stress in pounds per square inch
b = width perpendicular to pressure in inches
and h = depth in direction of force in inches

Compare resisting moments of following pairs 4" x 4" with 2" x 8"; 4" x 6" with 2" x 12"; and 6" x 8" with 3" x 16". The paired pieces have the same amount of material but the deeper is twice as strong. Cost, however, is a big factor. In some yards, dimension lumber over 12 inches deep costs extra so no studding deeper than 12 inches is recommended for spacing up to 6 feet. However, because of the extremely large stresses for 8-, 12-, and 16-foot spacing, 16-inch depth limit is used for posts. These sizes are usually available only on special order and at extra cost.

Plywood which is made by bonding 3, 5 or more plies of about 1/8 inch thick wood into one panel, commonly 4 by 8 feet in size, may be used for partition, wall and ceiling sheathing. For potato storages only the exterior glue-type structural grade C-C or C-D, or better, should be used. Table 6 based upon Douglas Fir Plywood Association Commercial Standard 45-55 and 122-56 shows the resisting moments of both west coast softwood Plyscord and Douglas Fir Plyscord. While 5/16- and 3/8-inch Western Softwood is listed, only 1/2 inch or thicker can be nailed to develop the full strength. (Glue and nailing would be required to develop full strength of thinner material.)

Sometimes corrugated galvanized steel and aluminum sheets are economical for sheathing of walls and bin partitions. Table 6 has been prepared to show the resisting moments of selected galvanized steel sheets. Usually only 26, 28, and 29 gage can compete in price with wood sheathing. Often rough lumber is cheaper than the lightest gage of metal.

Table 6.--Relative strength of various thickness of Western Softwood and Douglas Fir plywood when used as sheathing loaded parallel to surface plies

Nominal thickness	Western softwood 1/			Douglas fir 1/		
	Actual thickness	Section modulus 2/	Resisting moment 2/	Actual thickness	Section modulus 2/	Resisting moment 2/
Inches	Inches	Cubic inches	Inch pounds	Inches	Cubic inches	Inch pounds
5/16......	11/32	.219	296	5/16	.188	353
3/8.......	13/32	.311	420	3/8	.271	510
1/2.......	17/32	.484	655	1/2	.396	740
5/8.......	21/32	.669	900	5/8	.619	1,160
3/4.......	25/32	.847	1,140	3/4	.670	1,250

1/ Fiber stress Western Softwood is 1,350 lbs. per sq. in., Douglas Fir is 1,875 lbs. per sq. in.

2/ Section Modulus and Resisting Moment of parallel plies only. Perpendicular plies increase Section Modulus by separating plies but area of these plies does not support load. Figures based upon Douglas Fir Plywood Association CS-45-55 and CS-122-56.

The strength of corrugated metal sheets is directly proportional to the working stress of metal; the height of the corrugations; the width of the sheet and thickness of metal (gage) based on the Rankines formula:

$$W = 7S \times h \times b \times t/3L = \frac{7Shbt}{3L}$$

Where W = safe load on panel $b \times L$ in size, in pounds
S = working stress metal (use 16,000 psi for steel)
h = height of corrugations: .3 in. for 1-1/4 in. corrugation
.5 in. for 2-1/2 in. corrugation
b = width of panel in inches (use 12 in.)
t = thickness of metal in inches
L = span between supports in inches

Since the 1-1/4 inches corrugation sheet steel supports only 60 percent of the load supported by 2-1/2 inches corrugation sheets and the cost is about the same, only the 2-1/2 inches corrugation are recommended for partitions. The resisting moment of corrugated steel sheets shown in table 7 have been calculated for sheathing continuous over 3 or more supports when bending moment:

$$M = WL/10$$

Where W = total load in pounds
L = span between supports in inches

Table 7.--Strength and cost of corrugated sheet steel of various gages related to wood sheathing

Gage	Thickness of steel	Weight installed per square foot 1/	Resisting moments		Approximate cost as related to wood sheathing
			1¼-inch corrugations .3 inches deep	2½-inch corrugations .5 inches deep	
Number	Inches	Pounds	Inch-pounds	Inch-pounds	
18	0.0500	2.20	640	1,025	Equal 2 in. wood
20	.03750	2.17	480	770	Less than 2 in. wood
22	.03125	1.84	400	640	More than 1 in. wood
24	.02500	1.53	320	510	More than 1 in. wood
26	.01850	1.20	240	380	Equal to 1 in. wood
28	.01562	1.02	200	320	Less than 1 in. wood
29	.01406	.94	180	290	Less than 1 in. wood

1/ Weight installed per square foot is based on 1½ in. corrugations side lap and 6 in. end lap weight is for 2½ in. corrugations; that of 1¼ in. corrugated steel is about 1 percent less.

Selection of Vertical Structural Members

The bending moments of studding or posts caused by stored potatoes on selected walls are given in table 4. These values are multiplied by various stud spacing and matching resisting moments, selected from table 5, to get required studding or posts. The framing members thus selected are tabulated in table 8. One inch vertical sheathing can be used, without studding, to support thrust of up to 6 feet of potatoes in a 12-foot-high wall and 2-inch vertical sheathing supports up to 10 feet of potatoes in a 16-foot-high partition by merely nailing at sill and plate. This would only be used where there was no roof or axial load to be supported by a wall or partition.

In table 8 studding and posts are selected and spaced to take only the horizontal thrust of the potatoes. In most cases the axial load on partitions is relatively small and no extra framing is required. However, when ceiling or roof load is relatively large extra studding may be necessary.

Table 9 shows the safe unit axial load wall studding will support when not stressed by bending loads. The use of tables 8 and 9 to determine studding required for supporting both horizontal and vertical loads is illustrated in the following examples:

Example A: Select studding for basement bin partitions set 10 feet on center apart and are 10 feet high to support a thrust of a 8-foot-high pile of potatoes and the weight of the first floor packing room axial load of 200 pounds per sq. ft. (psf).

Solution: Table 8 shows that 2 x 6s studding 4 feet on center will support the potato thrust. Table 9 shows that 10-foot length 6s stud will support unit axial load of 1,018 per square inch or a 2 x 6 (9.15 sq. in.) will support 9,300 pounds. The axial load on partition 10 feet on center is 10 x 200 or 2,000 pounds/foot of wall. Each stud will support load on 9,300/2,000 or 4.65 feet of wall. Thus to support the potato thrust, the studding must be spaced 4 feet on center = 1/4 or 0.25 studs per foot; and to support the axial load, in addition, the studding must be spaced 4.65 feet on center = 1/4.65 or 0.22 stud per foot; therefore, for both loads, 0.47 stud per foot or 1 every 2.13 feet is required (fig. 9).

Example B: Studding is required for partitions set 20 feet on center apart and are 20 feet high to support a thrust of a 14-foot-high pile of potatoes and the weight of a flat roof axial load of 40 psf.

Solution: Table 8 shows that 2 x 12s studding 3 feet on center will support thrust of potatoes. Table 9 shows that 20-foot-high wall, 12s inch depth studs will support unit axial load of 1,058 psi or 2 x 12s (18.7 sq. in.) will support 19,800 pounds. The axial load on partitions is 40 x 20 or 800 pounds per foot of wall or each stud will support 19,800/800 or 25 feet of wall. Thus to support the potato thrust, the studding must be spaced 3 feet on center = .33 stud per ft.; and to also support an axial load, the studding must be spaced 25 feet on center = .04 studs per ft.; or, for both loads, .37 stud per foot or 1 for every 2.7 feet is required. Few builders would consider placing 2" x 12" studding 32 inches on center. However, 2" x 12" studding has 1,200/1,600 the strength of 2" x 12"s (structural) in bending and approximately

Table 8.--Sizes of studding and posts required when spaced various distances to support certain depths of potatoes with selected wall heights

Depth of potatoes	Height of wall	Sizes of studding and posts required when spaced							
		1.33 feet	2 feet	3 feet	4 feet	6 feet	8 feet	12 feet	16 feet
Feet	Feet	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
4.......	8	2 x 4	2 x 4	2 x 4	2 x 4	2 x 4	2 x 4	4 x 4	4 x 4
4.......	10	2 x 4	2 x 4	2 x 4	2 x 4	2 x 4	2 x 4	4 x 4	4 x 4
6.......	8	2 x 4	2 x 4	2 x 4s	2 x 6	4 x 4	4 x 4s	4 x 6	4 x 6s
6.......	12	2 x 4	2 x 4	4 x 4s	2 x 6	4 x 4	4 x 6	4 x 6	4 x 6s
8.......	10	2 x 4	2 x 6	2 x 6	2 x 6s	4 x 6	4 x 6s	4 x 8	4 x 8s
8.......	14	2 x 4s	2 x 6	2 x 6	2 x 6s	4 x 6	4 x 6s	4 x 8s	4 x 8s
10.......	12	2 x 6	2 x 6s	2 x 8	2 x 8s	4 x 8	4 x 8s	6 x 8s	6 x 10
10.......	16	2 x 6	2 x 6s	2 x 8s	2 x 10	4 x 8	4 x 8s	6 x 8s	6 x 10
12.......	14	2 x 6s	2 x 8s	2 x 10	2 x 10s	6 x 8	6 x 8s	6 x 10s	6 x 10s
12.......	18	2 x 6s	2 x 8s	2 x 10s	2 x 12	6 x 8	6 x 8s	6 x 10s	6 x 8
14.......	16	2 x 8s	2 x 10	2 x 12	2 x 12s	6 x 10	6 x 10s	6 x 12s	8 x 12s
14.......	20	2 x 8s	2 x 10s	2 x 12s	4 x 10	6 x 10	6 x 10s	6 x 12s	8 x 12s
16.......	18	2 x 10	2 x 12	4 x 10	4 x 12	6 x 10s	6 x 12s	8 x 12s	8 x 14s
16.......	22	2 x 10	2 x 12s	4 x 12	4 x 12	6 x 10s	6 x 12s	8 x 12s	8 x 14s
18.......	20	2 x 10s	2 x 12s	4 x 12	4 x 12s	6 x 12s	8 x 12s	8 x 14s	10 x 14s
18.......	24	2 x 12	4 x 10	4 x 12	4 x 12s	6 x 12s	8 x 12s	8 x 14s	8 x 16s
20.......	22	2 x 12s	4 x 12	4 x 12s	6 x 12	8 x 12s	8 x 14s	10 x 14s	10 x 16s
20.......	26	2 x 12s	4 x 12	4 x 12s	6 x 12s	8 x 12s	8 x 14s	8 x 16s	12 x 16s

1/ Nominal sizes listed but strength is based on dressed dimensions. The 1,200 psi grade lumber is shown unless size is followed by letter (s) thus 2 x 8s, when 1,600 psi stress grade is called for. For spacing up to 4 feet, studding depth is limited to 12 inches with most economical piece selected. For spacing 6, 8, 12, and 16 feet on center, posts with thickness equal to ½ or more of depth are selected.

Table 9.--Safe axial unit load in pounds per square inch on studding and posts of various depths and lengths, when used in partitions, to which sheathing has been attached to prevent buckling on smaller dimension

Depth of member of perpendicular partition	Safe axial unit load when length of studding or post is 1/									
	8 feet	10 feet	12 feet	14 feet	16 feet	18 feet	20 feet	22 feet	24 feet	26 feet
Inches	psi	psi	psi	psi	psi	psi	psi	psi	psi	psi
4	517	332	230							
4s	658	422	293	215						
6	1,241	800	554	406	312					
6s	1,580	1,018	705	517	397	313				
8		1,418	985	723	554	438				
8s		1,805	1,253	921	705	557	451			
10			1,571	1,159	890	707	567	470		
10s			2,000	1,475	1,132	897	722	598	503	
12					1,302	1,027	831	686	581	494
12s					1,657	1,307	1,058	873	739	629
14						1,418	1,146	945	800	680
14s						1,805	1,458	1,202	1,018	866
16								1,256	1,049	899
16s								1,599	1,335	1,144

1/ Based on the coefficient of elasticity of lumber, E = 1,210,000, except where letter (s) indicates structural grade, when E = 1,540,000. Data from the National Lumber Manufacturers "Wood Structural Design Data."

the same ratio (1,210,000/1,540,000) in supporting axial load. Therefore, 0.75 x 32 = 24 inch spacing could be used with 2" x 12" studding.

Example C: Posts are required for a removable partition, as illustrated in figure 10; otherwise conditions are the same as in B above.

Solution: From table 8 it is decided to use 6" x 12" posts 12 feet apart to support thrust of potatoes on plank partitions. Table 9 shows that

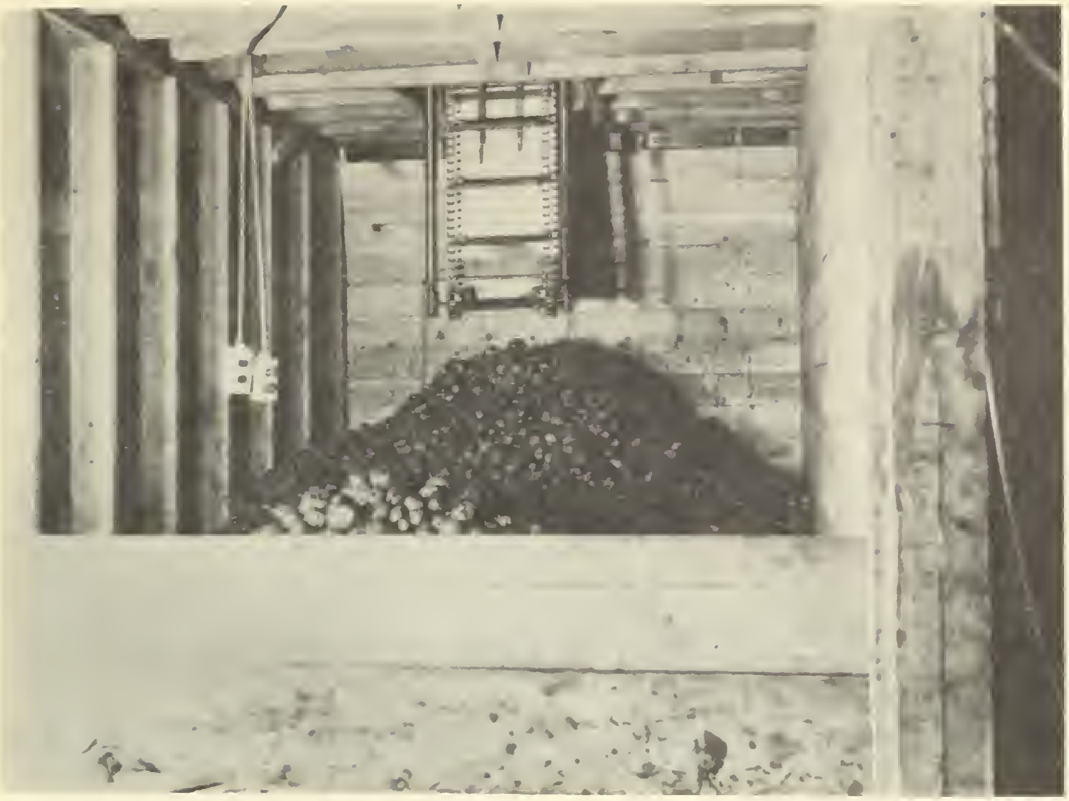

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Figure 9.--Potato storage bin showing studding in partition in manner given in Example A. The partition at the left is designed to support the overhead packing room where a load of 200 lbs. per square foot is expected. Note tight sheathing used on only one side of the studding for economy. With sheathing on only one side additional potatoes may receive major injury against exposed corners but in bins 10 feet wide 5 percent more potatoes can be stored than in bins using double boarded partitions.

20-foot-high walls, with 12s depth posts will support a unit axial load of 1,058 psi. For the 12- x 20-foot or 240 square foot area supported by posts at 40 psi, the axial load is 240 x 40 or 9,600 pounds. The extra width needed in addition to 6 x 12 to take the thrust is less than 1 inch, that is, 1,058 x 11.5 = 12,000 pounds per inch of 12-inch depth post. In this case, the next larger post, 8 x 12s, would be needed.

Selection of Horizontal Sheathing and Plank for Walls

The selection of suitable gage of corrugated sheet metal or thickness of plywood or wood for sheathing or bulkheads depends upon depth of the potato pile and the spacing of posts or studding. The strength or resisting moments of selected thicknesses and grades of lumber were given in table 5, and of plywood in table 6. Strength of selected sizes of corrugation and gage of corrugated sheet metal were given in table 7.

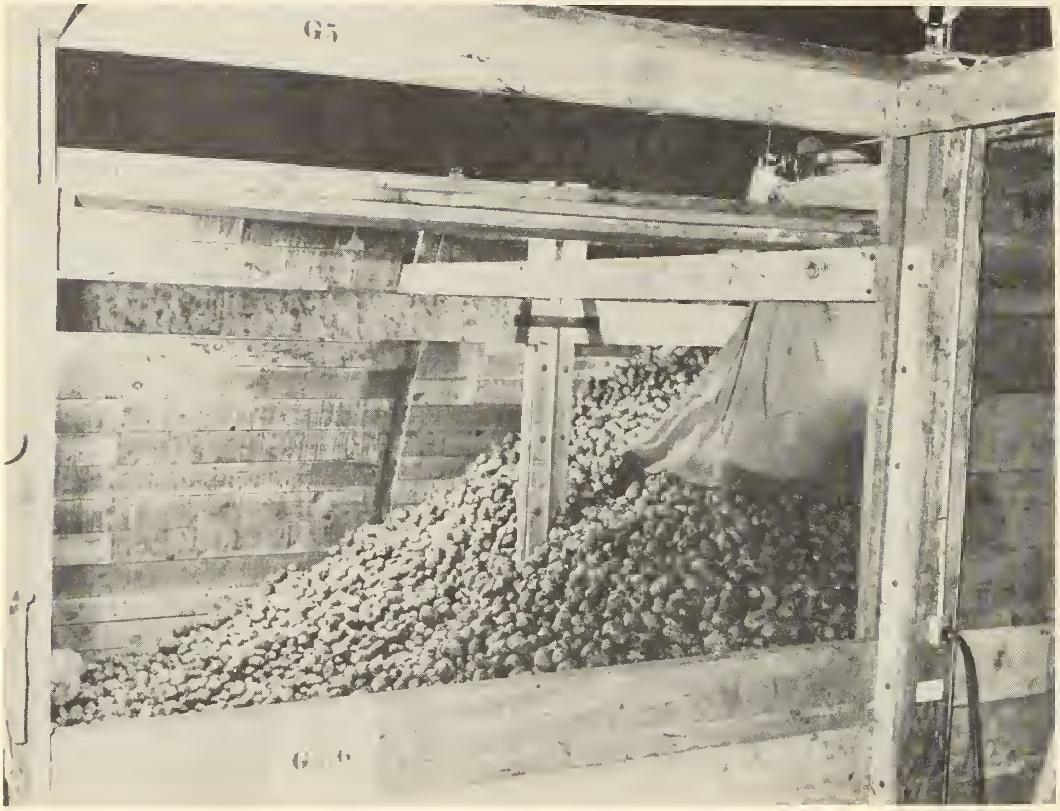

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Figure 10.--Potato storage bin showing features of removable partition in manner given in problem C. Two bins can be made into one larger bin by removing plank partition. When there is no need to separate lots or varieties, one large bin is easier to fill and empty than 2 small bins. In this instance roll-down velocity during filling is reduced by a sheet of canvas.

In selecting corrugated sheet steel for sheathing, only the 2½-inch corrugation sheets are considered here since these sheets are about 67 percent stronger than the 1¼-inch corrugated sheets of the same gage and cost. In addition no metal heavier than 26 gage should be used because plywood or 1-inch lumber will be both stronger and cheaper than the next heavier gage metal.

Table 10 has been prepared as a guide for selecting wood sheathing and bulkhead planks, for potato pressures up to 100 pounds per square foot and depths up to 20 feet. Note that corrugated sheet metal is adequate sheathing for 20-foot depth on studs 16 inches on center and for up to 12-foot depth on 2-foot centers (fig. 11). For greater depth of potatoes and span, 1- and 1s-inch wood sheathing is adequate up to 4-foot span and 18-foot depth. Table 11 has been prepared as a guide in selecting plywood and corrugated sheet metal sheathing for nailing on studding over 3 or more supports. This table shows thickness of Western Softwood and Douglas Fir plywood and gage of 2½-inch corrugation sheet steel for 16-inch, 24-inch, and 36-inch studding spacing for up to 20-foot depth of potatoes. Builders may choose between plywood and

Table 10.--Size of wood sheathing and bulkhead planks needed in horizontal partitions or bin fronts for various spacing of supports and for various depths and pressures of potatoes

Depth of potatoes	Potato pressure per square foot	Size of wood sheathing of bulkhead planks when 3 or more supports are spaced: 1/ 2/					Size of bulkhead planks when 2 supports are used and are spaced: 2/ 3/		
		2 feet	3 feet	4 feet	6 feet	8 feet	8 feet	12 feet	16 feet
Feet	Pounds	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
6......	45	1	1	1	1s	2	2	3	3s
8......	56	1	1	1	2	2	2	3	3s
10......	65	1	1	1	2	2	2s	3	4
12......	74	1	1	1s	2	2	2s	3	4
14......	82	1	1	1s	2	2s	3	3s	4s
16......	89	1	1	1s	2	2s	3	3s	4s
18......	95	1	1	1s	2	2s	3	3s	4s
20......	100	1	1	2	2	2s	3	3s	4s

1/ Thickness of wood sheathing is nominal for dressed sizes of 1,200 psi stress-grade except where 1,600 psi stress-grade is needed when thickness is followed by letter (s) thus 2s.

2/ Sheathing or bulkhead on 3 or more supports is relatively stronger than when on 2 supports. Maximum bending moment M over 3 supports being $M = WL/10$ while over 2 supports $M = WL/8$ where M = moment bending in inch-pounds. W = total load on member in pounds. L = span between support in inches.

3/ Planks 3 inches thick generally are needed for 12 feet or greater span. By putting in 1 or 2 removable posts to support bin bulkheads, spans can be reduced and 2-inch planks can be used for spans of 4 to 8 feet.

sheet metal on basis of local cost. Table 10 shows the nominal size of lumber required both for use as sheathing, when nailed over 3 or more supports and for bulkheads supported at ends only. Two-inch thick planks are generally used for 6- and 8-foot spans (fig. 12).

Bin partitions in new storages are usually spaced to over 20 feet on center. Three-inch, 4-inch or thicker bulkhead planks would be needed if supported only at ends as indicated in table 10. However, by providing removable posts, the bin fronts can be supported on posts 4 to 8 feet apart so that only 2-inch planks are needed for bulkheads. The posts selected in accordance with table 7 for 6- and 8-foot spacing have thickness equal or greater than half-depth. Such relatively thick posts, when supported in suitable floor and ceiling sockets, will not buckle when used to shorten the span of bin front bulkheads.

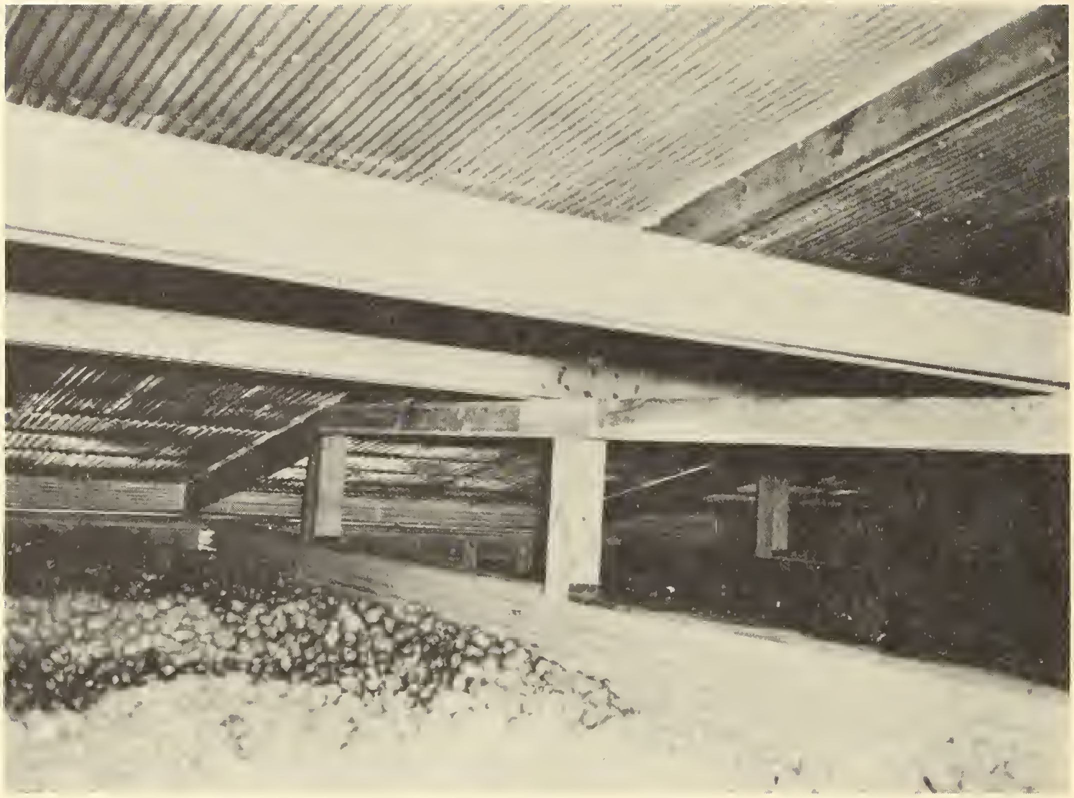

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Figure 11.--Upper 10 feet of the 14-foot-high bin walls in this storage are sheathed with 28 gage 2½-inch corrugated sheet metal, nailed to 1 side of studs 2 feet apart. Warehousemen like the metal because it is easy to keep clean. Here thrust of studding is taken by plate to posts with ties that cross 16 feet above floor. Ties are high enough to clear bin filling equipment.

Figure 13 shows an 18-foot wide bin where potatoes are supported by a bulkhead of sacked potatoes. Sometimes A-frame bulkheads 4 to 6 feet high are used in a similar manner. Many warehousemen would rather lose the storage space in fronts of wide bins rather than handle the long planks and removable posts necessary to support removable bulkheads. Naturally a much wider service alley is needed to fill bins to the top at the front as in figure 13. Unless the alley width is fully utilized, filling to a sloping front is practical from a narrow work alley. This may be as economical use of storage space as filling to top front of bin from a necessarily wider alley. Work alleys for conveyor equipment in modern storages are now often 20 to 30 feet wide compared with alley widths of 8 to 12 feet in old storages.

Tight boarding or edge-to-edge placement of partition boards and bulkhead planks is recommended. If this practice is followed, it develops the full strength of boards or planks and reduces the number of corners of boards or planks against which potatoes may be severely injured. Nailing sheathing on one side only of partition studding is recommended, because the value of gain in storage space is greater than the loss from additional injury. In using

Table 11.--Corrugated steel, Western Softwood and Douglas Fir Plywood needed for horizontal sheathing of potato bins, partitions and walls for various spacing of supports and for various depths and pressures of potatoes

Depth of potatoes	Potato pressure per square foot	Thickness of plywood						Gage of steel		
		Western Softwood stud spacing, inches			Douglas Fir stud spacing, inches			2½"-corrugated sheet steel stud spacing, inches 1/		
		16	24	36	16	24	36	16	24	36
Feet	Pounds	Inch	Inch	Inch	Inch	Inch	Inch	Gage	Gage	Gage
6......	45	5/16	5/16	1/2	5/16	5/16	1/2	29	29	2/24
8......	56	5/16	5/16	1/2	5/16	5/16	1/2	29	29	2/22
10......	65	5/16	3/8	5/8	5/16	5/16	1/2	29	28	2/20
12......	74	5/16	3/8	5/8	5/16	3/8	5/8	29	26	20
14......	82	5/16	3/8	5/8	5/16	3/8	5/8	29	2/24	18
16......	89	5/16	1/2	3/4	5/16	1/2	3/4	29	24	18
18......	95	5/16	1/2	3/4	5/16	1/2	3/4	29	24	18
20......	100	5/16	1/2	3/4	5/16	1/2	3/4	29	24	16

1/ Where corrugated steel is used, 2½ inch is recommended because it is about 40 percent stronger than same gage 1¼ inch corrugated sheets.

2/ When 26 gage steel is not adequate, 1 inch wood is used because it is cheaper than heavier steel.

(Note bending moment $M = \frac{WL}{10}$ for sheating supported at 3 or more points.)

corrugated metal sheathing for roofs, nailing is always on the crowns of the corrugations. This insures water tightness and permits expansion and contraction without enlarging nail holes. In partitions nailing may be in the valleys, so potatoes are not injured on exposed nail heads. Here water tightness is not necessary and the relatively uniform storage temperature minimizes expansion and contraction of the metal.

RECOMMENDATIONS

No single recommendation can be made for storage walls, partitions, or bin fronts because potato bin width and the depth of potatoes in the bin vary so much. Builders may use the tables in selecting locally available framing, sheathing, and bin fronts. The cheaper rough lumber is satisfactory for partitions but, because rough framing members vary in dimensions, it is unsuitable for walls. Structural grade framing costs more per foot but because smaller sizes can be used for the same strength it may cost less than common grade lumber to use.

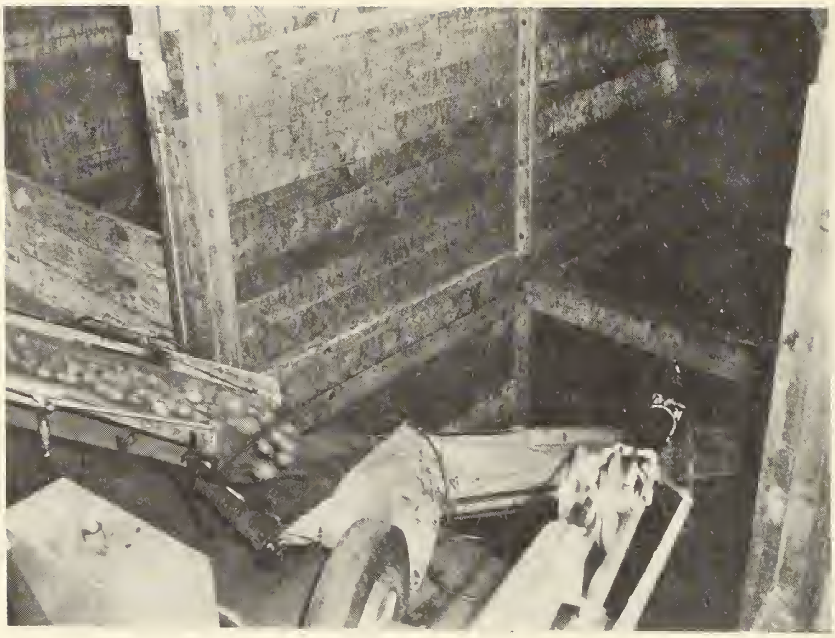

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Figure 12.--Plank partition 20 feet high with span of 9 feet. Here lower one-third of planks are 3 inches thick and upper two-thirds are 2 inches thick.

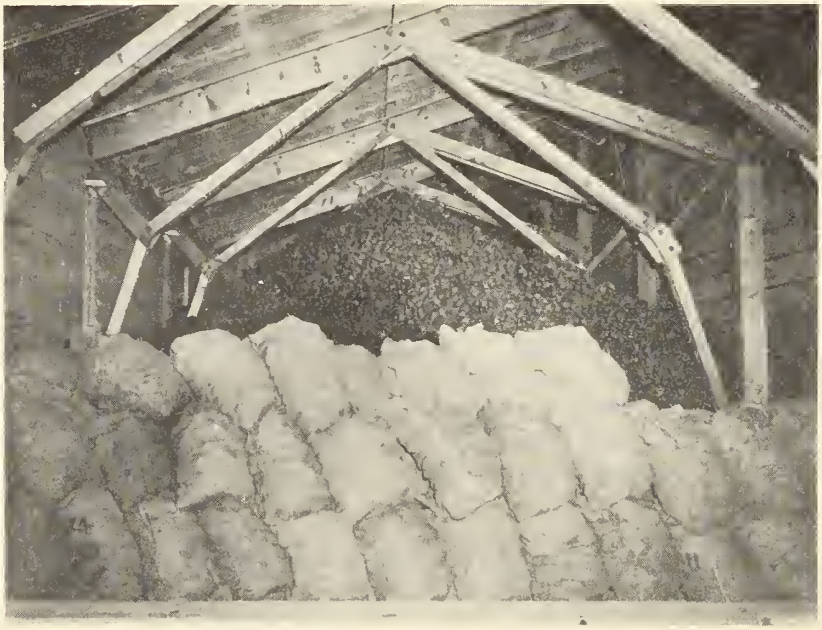

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Figure 13.--The walls of this bin are made of 2-inch planks spiked to posts spaced 10 feet apart. The sacked potatoes act as a bulkhead to hold back potatoes stored 10 feet deep. If a bulkhead were used for this 18-foot span, 4-inch planks and posts, or other bracing would be required.

Timber framing is usually more economical than framing with steel I-beams or other shapes. Lumber is less expensive than concrete for walls. Concrete foundation walls should extend about a foot above grade and the partition curb extend 6 inches above the inside floor. Higher concrete walls and curbs must be well reinforced with steel and are therefore relatively expensive. The sill of a frame wall or partition should be anchored to the concrete foundation wall or partition curb with 5/8-inch anchor bolts spaced 24 inches apart. These bolts should extend 2 feet down into the concrete of deep foundations and into the lower half of the footings of shallow foundation walls or curbs.

Other publications on related subjects are:

White Potato Storages for New Jersey, Long Island, and Southeastern Pennsylvania. Marketing Research Report No. 70. June 1954.

An Improved Elevator for Deep Bin Potato Storages. Marketing Research Report No. 131. August 1956.

Flume Systems for Handling Bulk Stored Potatoes. Marketing Research Report No. 177. June 1957.

Storage of Fall-Harvested Potatoes in the Northeastern Late Summer Crop Area. Marketing Research Report No. 370. January 1960.

Single copies of the above publications are available from the Office of Information, U. S. Department of Agriculture, Washington 25, D. C.

Wood Handbook. Agriculture Handbook No. 72. 1955. (For sale by Superintendent of Documents, Government Printing Office, Washington 25, D. C., at $2.00 a copy.)

A Light-Weight Conveyor for Filling Deep Bin Potato Storages. AMS-362. February 1960.

For a copy, write to the Agricultural Marketing Service, U. S. Department of Agriculture, Washington 25, D. C.

Methods of Receiving Potatoes in Barrels at Maine Trackside Storages. Maine Agricultural Experiment Station Bulletin 560. June 1957.

Mechanized Methods of Receiving Potatoes at Maine Trackside Storages. Maine Agricultural Experiment Station Bulletin No. 585. September 1959.

For copies, write the Agricultural Experiment Station, Orono, Maine.